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# Task 4 Improvised Nuclear Device Response Curves

M. Alai, S. Neuscamman

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LLNL-TR-

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Maureen Alai and Stephanie Neuscamman
Lawrence Livermore National Laboratory

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**Tables**

# 1 Modeling and Simulations in Support of the Any City Planner Resource

The Department of Homeland Security, Science and Technology Directorate (DHS S&T) has tasked Lawrence Livermore National Laboratory (LLNL) under IA HSHQPN-14-X-00216 Task 4 “Identification of uncertainty drivers in support of Federal Emergency Management Agency’s (FEMA) Statistically-Based Planning Tool”. Task 4 was funded with the support of FEMA’s Chemical Biological Radiological Nuclear and Explosive (CBRNE) Office Improvised Nuclear Device (IND) Branch who has separately tasked LLNL under IA HSFE50-15-X-0283 to develop a planning resource using a new statistically based approach, called the IND City Planner Resource (iCPR). The S&T funded Task 4 represents the foundation effort in developing this new FEMA resource by providing the funding to support the necessary large number of simulations that will provide the technical basis of the iCPR.

Currently, FEMA performs IND analyses for one major United States (US) city at a time using one specific hypothetical IND scenario. The detailed analyses of the single scenario are used to support FEMA’s Information Analysis phase of the planning process (FEMA Operational Planning Manual, 2014). While well received and highly valued, the detailed city-specific analyses for the single scenario require significant cost and time, and continuing to perform analyses in this manner for numerous cities across the US is not sustainable. FEMA has therefore identified a new approach to develop a software resource that can provide IND effects in a more time and cost efficient manner for a much larger number of communities.

This new approach will provide IND related information and effects for IND related Key Planning Factors (KPF) for 60 major US cities, of which 58 are Tier 1 and Tier 2 Urban Areas Security Initiative (UASI) cities, (Table 1) utilizing a robust, statistically based methodology. Development of the resource leverages past efforts by DHS S&T and FEMA by using the extensive IND analyses that have been completed for 10 major US cities identified in Table 2. However, those are not sufficient to make the correlations needed to develop a robust tool and develop an understanding of correlations between city characteristics (weather, infrastructure, population) and IND effects. Additional analyses need to be performed to determine the uncertainties and response curves to make these correlations. To this end, under Task 4, LLNL performed model simulations and analyses to identify and provide response curves (expressed as two dimensional contours) for radioactive fallout deposition, transport, population, and blast overpressure as a function of yield, weather, location and time. These contours can then be further combined and correlated with infrastructure and population databases to estimate city specific effects on KPFs such as impacted infrastructure and casualty rates.

**Table 1. iCPR Cities**

| City | 2010 Census Population | Tier | | City | 2010 Census Population | Tier |
|---|---|---|---|---|---|---|
| Albuquerque, NM | 545,852 | N/A | | Las Vegas, NV | 583,756 | Tier 2 |
| Colorado Springs, CO | 416,427 | N/A | | Louisville, KY | 597,337 | Tier 2 |
| Boston, MA | 617,594 | Tier 1 | | Memphis, TN | 646,889 | Tier 2 |
| Chicago, IL | 2,695,598 | Tier 1 | | Miami, FL | 399,457 | Tier 2 |
| Dallas, TX | 1,197,816 | Tier 1 | | Milwaukee, WI | 594,833 | Tier 2 |
| Houston, TX | 2,100,263 | Tier 1 | | Minneapolis, MN | 382,578 | Tier 2 |
| Los Angeles, CA | 3,792,621 | Tier 1 | | Nashville, TN | 601,222 | Tier 2 |
| New York, NY | 8,175,133 | Tier 1 | | New Orleans, LA | 343,829 | Tier 2 |
| Newark, NJ | 277,140 | Tier 1 | | Norfolk, VA | 242,803 | Tier 2 |
| Philadelphia, PA | 1,526,006 | Tier 1 | | Oklahoma City, OK | 579,999 | Tier 2 |
| San Francisco, CA | 805,235 | Tier 1 | | Omaha, NE | 408,958 | Tier 2 |
| Washington DC | 601,723 | Tier 1 | | Orlando, FL | 238,300 | Tier 2 |
| Providence, RI | 182,911 | Tier 2 | | Phoenix, AZ | 1,445,632 | Tier 2 |
| Albany, NY | 97,856 | Tier 2 | | Pittsburgh, PA | 305,704 | Tier 2 |
| Atlanta, GA | 420,003 | Tier 2 | | Portland, OR | 583,776 | Tier 2 |
| Austin, TX | 790,390 | Tier 2 | | Richmond, VA | 204,214 | Tier 2 |
| Bakersfield, CA | 347,483 | Tier 2 | | Riverside, CA | 303,871 | Tier 2 |
| Baltimore, MD | 620,961 | Tier 2 | | Rochester, NY | 210,565 | Tier 2 |
| Buffalo, NY | 261,310 | Tier 2 | | Sacramento, CA | 466,488 | Tier 2 |
| Charlotte, NC | 731,424 | Tier 2 | | Salt Lake City, UT | 186,440 | Tier 2 |
| Cincinnati, OH | 296,943 | Tier 2 | | San Antonio, TX | 1,327,407 | Tier 2 |
| Cleveland, OH | 396,815 | Tier 2 | | San Diego, CA | 1,307,402 | Tier 2 |
| Columbus, OH | 787,033 | Tier 2 | | San Jose, CA | 945,942 | Tier 2 |
| Denver, CO | 600,158 | Tier 2 | | Seattle, WA | 608,660 | Tier 2 |
| Detroit, MI | 713,777 | Tier 2 | | St. Louis, MO | 319,294 | Tier 2 |
| El Paso, TX | 649,121 | Tier 2 | | Syracuse, NY | 145,170 | Tier 2 |
| Hartford, CT | 124,775 | Tier 2 | | Tampa, FL | 335,709 | Tier 2 |
| Indianapolis, IN | 820,445 | Tier 2 | | Toledo, OH | 287,208 | Tier 2 |
| Jacksonville, FL | 821,784 | Tier 2 | | Tucson, AZ | 520,116 | Tier 2 |
| Kansas City, MO | 459,787 | Tier 2 | | Tulsa, OK | 391,906 | Tier 2 |

**Table 2. Previously modeled cities**

| City | Tier | Funding Agency |
|---|---|---|
| New York, NY | Tier 1 | FEMA and DHS/S&T |
| Boston, MA | Tier 1 | FEMA |
| Washington DC | Tier 1 | FEMA and DHS/S&T |
| San Francisco, CA | Tier 1 | DHS/S&T |
| Houston, TX | Tier 1 | FEMA and DHS/S&T |
| Chicago, IL | Tier 1 | FEMA and DHS/S&T |
| Los Angeles, CA | Tier 1 | DHS/S&T |
| Miami, FL | Tier 2 | DHS/S&T |
| Seattle, WA | Tier 2 | DHS/S&T |
| Oklahoma City, OK | Tier 2 | DHS/S&T |

# 2 Simulation Data

LLNL performed fallout and nuclear blast modeling for the 60 iCPR cities using the NARAC modeling system and predominant weather patterns determined in a previous Task 4 effort (Alai, et al., 2015). The model analyses were performed to develop response curves that will be used to develop city specific KPFs planning products for iCPR.

## 2.1 Data Format

The simulation data generated for the response curves is in the form of NetCDF files. NetCDF Network Common Data Form files are used for storing and sharing array oriented scientific data. NetCDF files are self-describing in that they include information about the data it contains. They are also portable since they can be accessed by computers with different methods of storing integers, characters, and floating point numbers. The data can be accessed from a variety of programming and scripting languages.
The data in the response curve data file vary on the parameters for the 600 scenarios modeled:

- 60 cities
- 2 yields: 1kT and 10kT
- 5 weather patterns: Year Long, Winter, Spring, Summer, Fall

The data in the NetCDF file contains time varying data as a function of the scenario specific terrain, weather, population, and yield. For each scenario, there are 4 categories of NetCDF data files:

- Prompt effects (for prompt effects, there is an additional comma separated values (csv) file)
- Radiation Integrated Dose
- Radiation Dose Rate
- Atmospheric Fallout 3-dimensional location

This data is then used to derive the scenario specific IND KPF planning products such as injury/casualty calculations, dose reduction through building shelter, and location of fallout zones.

## 2.2 Data Storage

The simulation data including input files to the fallout and blast models and the output data for the response curves in the form of NetCDF files is stored on a 30 terabyte server and storage system purchased by DHS S&T under IA HSFE50-15-X-0283. The server system consists of a Hewlett Packard DL380 processing server and Hewlett Packard MSA 2040 storage system. The server and storage system will reside in LLNL's (Unclassified) Data Center in Building 112. The server system will also be used to store post processed data and the final IND KPF planning products that will be available separately through the iCPR. The server is partitioned into two sections, one for data and the other for post processing and final planning product storage. The data section contains all of the simulation data and response curves.

## 2.3 Data Access

DHS S&T will be able to access the data through a request to one of the following:

- LLNL Project Manager: Maureen Alai alai1@llnl.gov
- LLNL Program Leader: Amy Waters waters4@llnl.gov
- LLNL GS IT Manager: Lisa Belk belk3@llnl.gov

## 2.4 Data Applications

The data generated through Task 4 is extensive and unique. There are 3 different capabilities/data sets developed through this effort that have the potential for use in other applications.

1. K-means statistical clustering applied to 10 years of vertical weather data (Alai, et al., 2015).
2. Predominant weather patterns for 60 US cities and the corresponding 10 years of vertical weather data.
3. Response curves for 60 cities encompassing 600 different IND scenarios with fallout results varying by different terrain, weather, and yields (1kT and 10kT).

The K-means statistical clustering applied to the weather data for this Task focused on optimization for 1kT and 10kT detonations (with emphasis on upper level winds for fallout transport). However, the methodology could be modified to optimize for other yields or other applications such as an RDD, chemical, and biological releases. As an example, for an RDD, the near surface winds would potentially be more important than the upper level winds. The clustering method would be adapted as appropriate (weighting lower level winds heavier than the upper level winds). The clustering method optimized for the selected release would be applied to the 10 years vertical weather profiles already stored and available from this Task.

The predominant weather patterns for the 60 US cities for the year long and 4 seasons could be used on other applications where knowledge of predominant weather patterns applicable to an IND would be useful such as in Task 3 of this IA by informing the development process of the variation in impacted areas due to yield and weather. As additional IND planning and response applications are developed, this data set provides a good foundation for scoping and development of new capabilities.

The response curves developed for 600 IND scenarios represent a complex set of weather, population, infrastructure, prompt effect, and fallout data. While the application to the iCPR and the FEMA regional planning community is clear, there could be additional applications and benefits of this information to a broader audience such as state and local agencies interested in understanding the effects of an IND detonation in a city.

# 3 Summary

LLNL performed extensive modeling and simulations to determine the response curves to correlate city characteristics and Key Planning Factors under IA HSHQPN-14-X-00216 Task 4 “Identification of uncertainty drivers in support of Federal Emergency Management Agency’s (FEMA) Statistically-Based Planning Tool”. This DHS S&T funded effort is in support of the development of FEMA’s iCPR. Task 4 represents the foundation effort in developing this new resource by providing the necessary and large number of modeling simulations that will provide the scientific technical basis of the iCPR.

The Task 4 effort resulted in a developing a new statistical clustering technique ; acquiring, validating, and storing10 years of vertical weather profiles for future use; and generating response curves and IND effect data for 600 different scenarios for application in the iCPR and for potential in future efforts in other IND applications. The iCPR development has established a framework that could be applied to a broader use for a Chemical Biological Radiological and Nuclear (CBRN) planning tool. The same approach used in the iCPR could be used in developing a suite CBRN CPRs (cCPR, bCPR, rCPR) that would provide planning information for a variety of disaster scenarios.

# 4 References

FEMA, 2014. FEMA Operational Planning Manual, FEMA P-1017.

Alai, M., Lennox, K., Neuscamman, S., Alves, S., Kasi, K., 2015. Improvised Nuclear Device City Planner Resource Uncertainty Drivers. LLNL-MI-676031.

# Acronyms and Abbreviations

| | |
|---|---|
| bCPR | Biological City Planner Resource |
| cCPR | Chemical City Planner Resource |
| CBRN | Chemical Biological Radiological Nuclear |
| CBRNE | Chemical Biological Radiological Nuclear and Explosive |
| csv | Comma separated values |
| CPR | City Planner Resource |
| DHS/S&T | Department of Homeland Security Science and Technology Directorate |
| FEMA | Federal Emergency Management Agency |
| FY | Fiscal Year |
| GS IT | Global Security Information Technology |
| IND | Improvised Nuclear Device |
| iCPR | Improvised Nuclear Device City Planner Resource |
| KPF | Key Planning Factors |
| LLNL | Lawrence Livermore National Laboratory |
| rCPR | Radiological City Planner Resource |
| RDD | Radiological Dispersal Device |
| UASI | Urban Areas Security Initiative |
| US | United States |